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CENTRO DI STUDIO PER LA FISICA DELLE MICROONDE
FIRENZE

CONSIGLIO NAZIONALE DELLE RICERCHE

329 900

FINAL REPORT

CONTRACT AF 61 (052) - 182

September 1960

MAINTENANCE AND OPERATION
OF A DOPPLER DATA RECORDING STATION

PART II: IONOSPHERIC MEASUREMENTS

Author:

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PART II

1 - Introduction

As noticed in Part I of the Final Report of the present Contract, a program of ionospheric research by means of the 20 MHz signals from artificial satellites has been developed at the Centro Microonde, contemporaneously with the tracking activity.

To this end the curves of the amplitude of the incoming signals have been recorded versus time, at the same time as the Doppler curves required for the tracking program.

By investigating the variations of the amplitude and phase of the received signals, these records allow some information about the structure of the ionosphere to be derived.

All the recordings collected during the present Contract refer to signals of satellite 1958 02.

However, due to the pulse modulation of the signals of this satellite, the Doppler curves could not be used for ionospheric investigations because the frequency shifts could not be measured with the accuracy required to detect a very small irregular change of phase. In only a few cases, when the irregularities in the electronic content of ionosphere were particularly large, could their effects be observed on the Doppler curves.

In the present Report the amplitude records will be examined and some results which may be deduced from them will be presented.

The main phenomena observed are: scintillation, fade out, Faraday rotation, and hop propagation.

2 - Equipment

The equipment and methods used for recording the Doppler curves are described in sec. 2.1 of Part I of the Present Final Report.

It is to be noted that, with such equipment, Doppler and amplitude curves cannot be simultaneously recorded by using the sam

receiver, due both to the presence of the local heterodyne and to the fact that amplitude variations are introduced by the operator when he follows manually the Doppler shifts.

Accordingly a different antenna and a receiver were employed for the amplitude records and for the Doppler records.

The antenna used for amplitude records is at a distance of about 100 meters from the antenna for Doppler records, and is of the same type. It is oriented N-S, and is connected via a cable RG8/U, 100 meters long, to a communication receiver Collins 390A/URR.

The output of the receiver diode is connected, through a D.C. amplifier, to a recorder Esterline Angus mod. AW, 1mA full scale (fig.2.1). The resistances in series to the measuring element are high enough to avoid damping due to the external circuit.

The R.F. gain of the receiver is adjusted according to the maximum level expected during each transit.

After each transit, the receiver is connected to a signal generator GR805C in order to carry out the calibration with signals of known amplitude.

Due to the remarkable difference between the antenna and receiver impedances, the calibrations are marked on the records only in relative value. The absolute value can be evaluated.

A time-marker pen, driven by the same time signals used for the Doppler curves, traces a mark each second on a border of the records of the Esterline Angus.

The band width of the receiver was chosen time by time according to the presence of interferences.

3- Scintillation

With the word 'scintillation' we intend any random amplitude or phase variation, observed on the records, caused by irregularities of the medium crossed by the signals, which superimposes to the normal variation due to the motion of the satellite.

Obviously, attention must be paid not to confuse scintillation with fluctuation due to the change of the modulation pattern or to measurement errors.

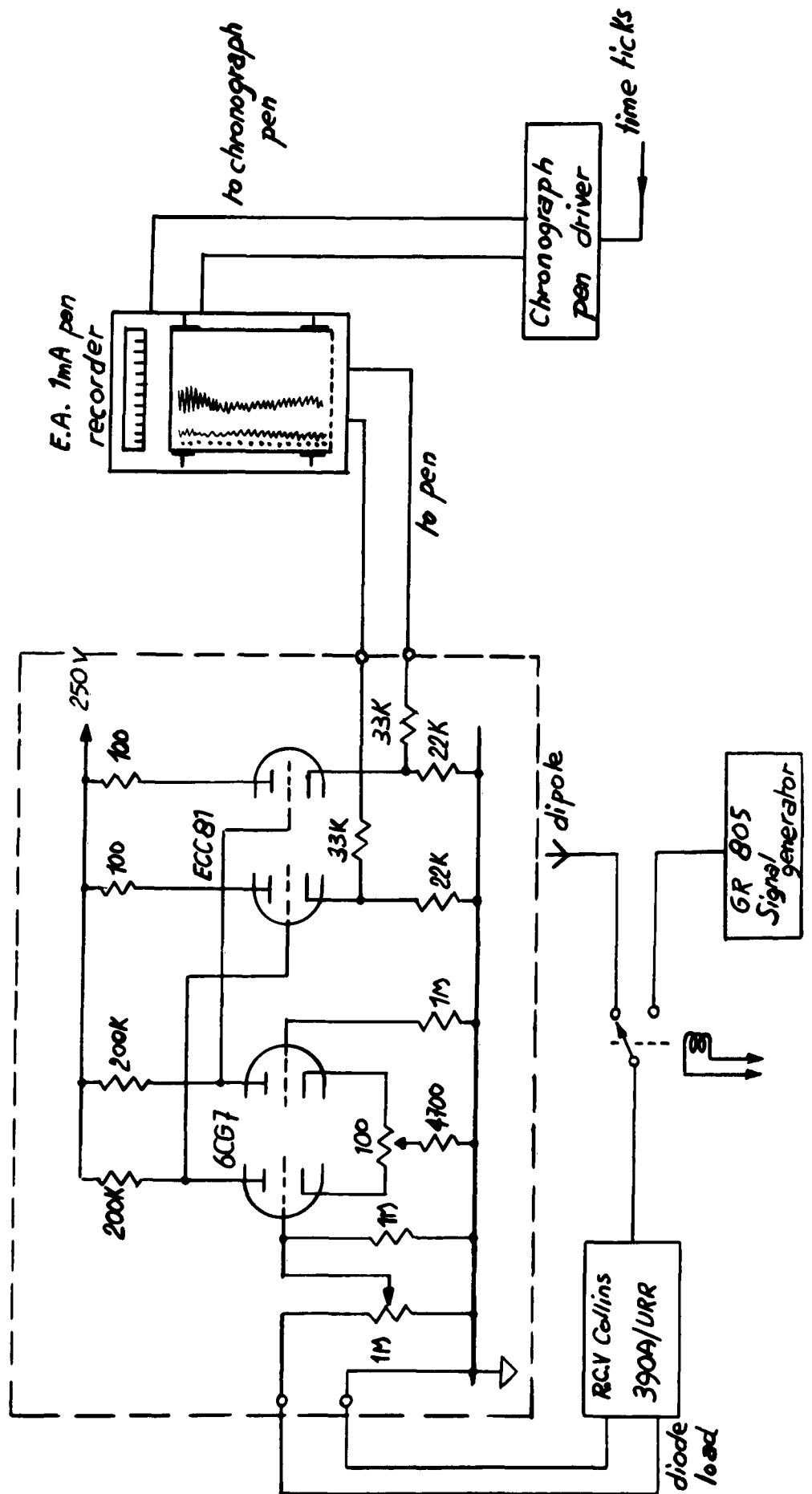


Fig. 2.1

Accordingly, only sufficiently high irregularities in the records surely recognizable as scintillations will be examined and discussed.

When a satellite travels very high, over the maximum of the F-region, scintillation is rarely observed. Weak scintillation has been observed during three early morning transits in successive days. On the contrary, scintillation has always been observed during low transit, in positions in which the satellite is seen at large zenith angles.

Two typical examples of signals affected by amplitude scintillation are shown in Fig. 3.1. The upper pattern refers to a relatively high transit, the lower one to a relatively low transit. Fig. 3.2 shows a Doppler curve affected by phase scintillation.

Sometimes amplitude and phase scintillation occurred simultaneously. The observations of amplitude and phase scintillation are listed respectively in the third and fourth columns of Table I.

Fig. 3.3, 3.4, and 3.5 show the subsatellite tracks (entire line) corresponding to the revolution listed in Table I.

The portions corresponding to amplitude or phase scintillation are marked differently.

4 - Fade out

Another phenomenon affecting the signals is the 'fade out'. An example is shown in Fig. 4.1. At a given time the signal disappears and then starts again after a short time.

Fade out has been observed at the times listed in the fifth column of Table I. The position of the satellite corresponding to the fade out of the signal was determined for a number of transits. Fig. 4.2 and 4.3 show the subsatellite tracks (entire line). The dashed portion of an entire line indicates the zone corresponding to complete fade out. The other zone differently marked refers to a signal which arrived greatly attenuated in comparison with near zones.

It appears that the positions of the satellite, corresponding to the fade out of the signal, are very near to one another during different passages.

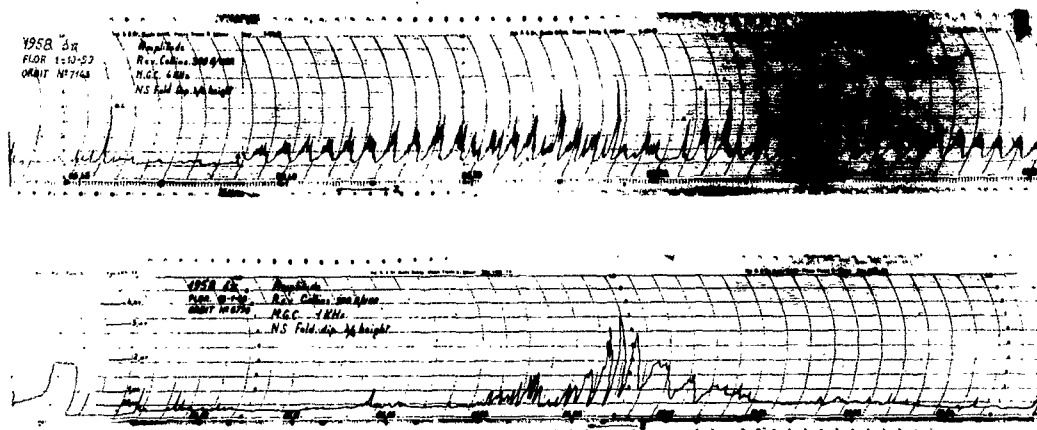


Fig 3.1

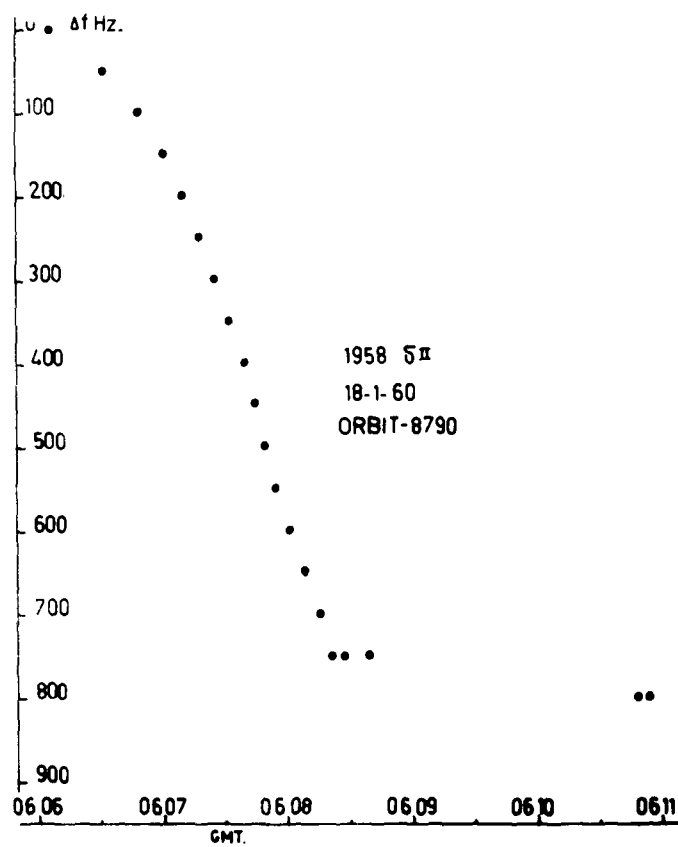


Fig 3.2

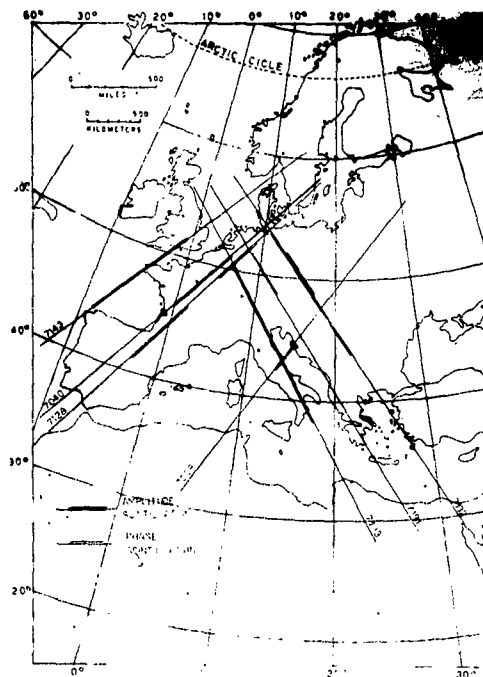


FIG 3.3

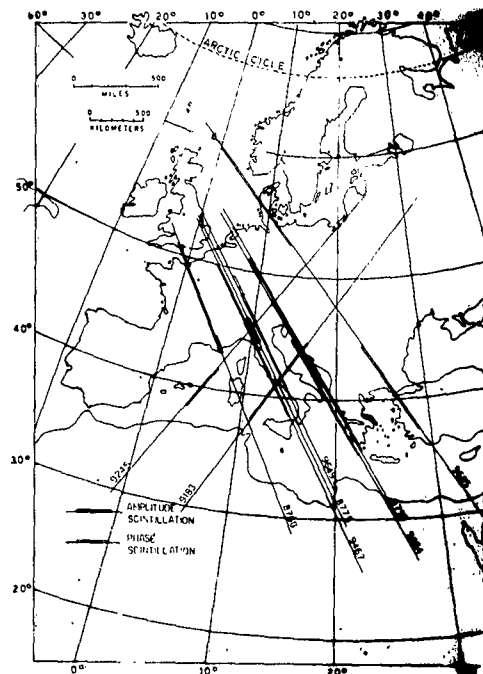


FIG 3.4

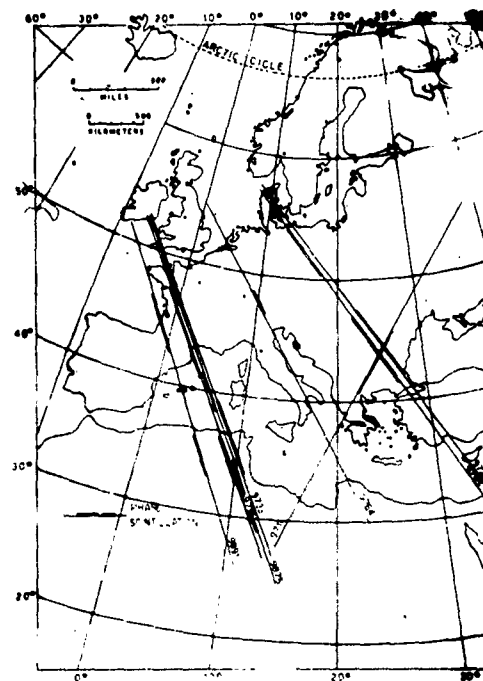


FIG 3.5

| RIV. | C.A. | AMPLITUDE SCINTILL. | PHASE SCINTILL. | FADE OUT | STRONG ATTENUAT. | FARADAY INV.POINT | HOP PROPAG. | MOD. CHANG |
|-------|--------|------------------------|--------------------|-----------|---------------------|----------------------|----------------|---------------|
| 6330 | | | | | 0356-0359 | | | |
| 7040 | | | 0701-0703 | | 0701-0702 | | | |
| 7054 | 054008 | | | 0542-0542 | 0539-0541 | | | |
| 7069 | | | | | 0556-0558 | | | |
| 7085 | | | | 0435-0435 | 0437-0438 | | | |
| 7098 | 045130 | | 0451-0452 | | | | | |
| 7103 | 132018 | 1318-1322 | | | | | | |
| 7127 | | | | 0344-0344 | | | | |
| 7128 | | | 0520-0522 | | 0520-0521 | | | |
| 7132 | | 1210-1213 | 0524-0525 | | 0524-0525 | | | |
| 7133 | | 0537-0539 | 1210-1211 | | | | | |
| 7137 | | | | | | | | 1227-1228 |
| 7151 | | | | | | | | 1242-1243 |
| 7172 | | | | 0429-0429 | | | | |
| 7177 | | | | | | | | 1256-1257 |
| 7185 | 130330 | | | 0300-0301 | 0303-0304 | | | |
| 7191 | | | | 0305-0305 | | | | |
| 7206 | | | 1126-1130 | | | | | 1132-1132 |
| 8321 | | | | | | 150130 | | 1144-1144 |
| 8502 | | | | | | 113122 | | |
| 8517 | 112427 | | | | 1123-1124 | | | |
| 8532 | | | | | | 105155 | | |
| 8623 | | | | | | 092704 | | |
| 8699 | | | | | | 081330 | | |
| 8760 | 072419 | 0721-0723 | 0723-0724 | | 0724-0726 | | | |
| 8775 | 064617 | 0645-0646 | 0645-0646 | | | | | |
| 8790 | 060745 | 0606-0609 | 0608-0610 | | | | | |
| 9045 | | | | 1720-1720 | | | | |
| 9060 | | | | | 1638-1639 | | | |
| 9183 | | 1418-1420 | | | | | | |
| 9245 | 134000 | | 1337-1338 | | 1336-1342 | | | |
| 9338 | | | | | | 121910 | | |
| 9400 | | | | | | 111108 | | |
| 9431 | | | | | | 103242 | | |
| 9462 | | | | | | 095109 | | |
| 9467 | 174731 | 1745-1749 | | | | | | |
| 9544 | | | 0559-0600 | | | | | |
| 9554 | 135427 | | 0601-0602 | | | | | |
| 9555 | | | 1352-1353 | | | | 1352-1353 | |
| 9605 | | | 1354-1357 | | | | 1355-1356 | |
| 9711 | | | | | | | 0315-0316 | |
| 9732 | 111400 | | 1213-1245 | | | | 1245-1246 | |
| 9733 | 131557 | | 1246-1250 | | | | 1247-1248 | |
| 9748 | | | 0313-0315 | | | | | |
| 9764 | 115723 | | 1114-1146 | | | | 1114-1115 | |
| 9770 | | | 1317-1319 | | | | 1318-1319 | |
| 9793 | | | | | | | 1145-1149 | |
| 9795 | | | | | | | 1153-1154 | |
| 9843 | | | 1157-1157 | | | 115712 | | |
| 9874 | | | | | | | 1200-1201 | |
| 9875 | | | | | | | 1203-1203 | |
| 9891 | 103048 | | 1033-1034 | | | | 1035-1036 | |
| 9907 | | | 1035-1037 | | | | 1209-1209 | |
| 9938 | | | 1035-1037 | | | | | |
| 9954 | | | 1035-1037 | | | | | |
| 9970 | | | 1205-1207 | | | | | |
| 9986 | | | 1209-1210 | | | | | |
| 10002 | | | | | | 103900 | | |
| 10011 | | | | | | 103115 | | |
| 9874 | | | | | | | 0904-0905 | |
| 9875 | | | 1032-1033 | | | | 0905-0905 | |
| 9875 | | | 1035-1036 | | | | 0906-0906 | |
| 9875 | | | 1036-1038 | | | | 1033-1033 | |
| 9875 | | | 1028-1029 | | | | 1036-1037 | |
| 9875 | | | 1031-1032 | | | | | |
| 9891 | 103048 | | | | | | | |
| 9907 | | | | | | | 1025-1025 | |
| 9938 | | | | | | 083330 | | |
| 9954 | | | | | | 082035 | | |
| 9970 | | | | | | 080355 | | |
| 9986 | | | | | | 074415 | | |
| 10002 | | | | | | 072043 | | |
| 10011 | | | | | | 064006 | | |



FIG. 4.1

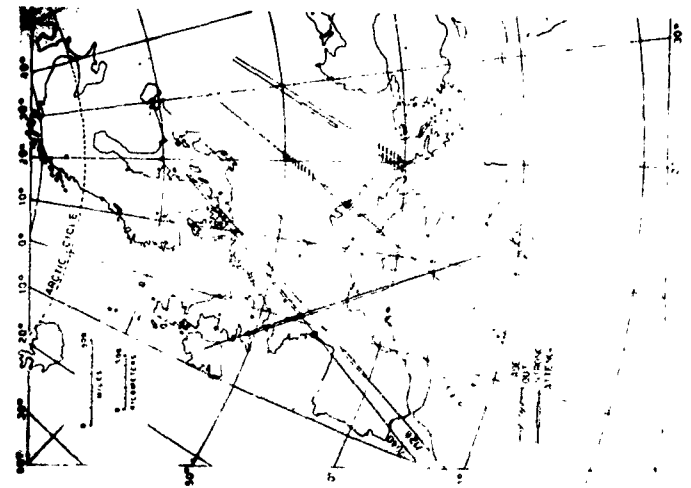


FIG. 4.2

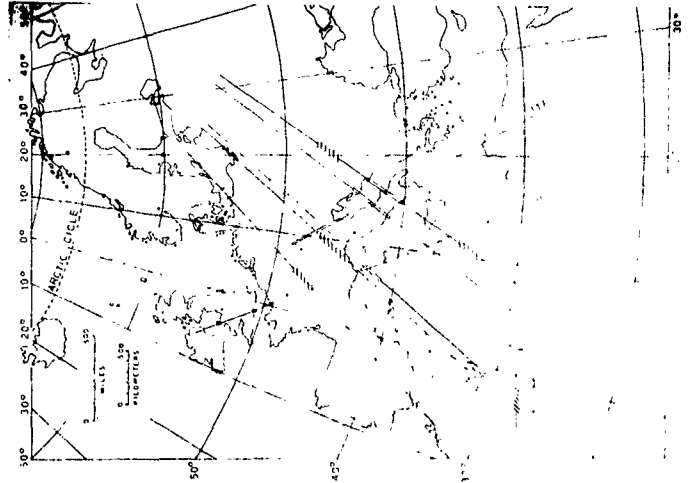


FIG. 4.3

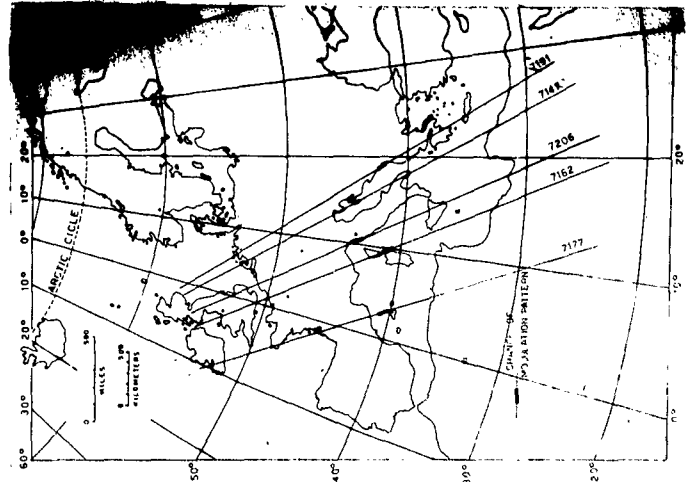


FIG. 4.4

This fact could suggest the presence of a zone of ionosphere where fade out should take place; in this case, fade out would be a particular type of scintillation. However, another possible explanation is the following.

Fade out may be due to the zeros of the radiation pattern of satellite antenna, being directed towards the receiving station. The persistence of the region where the fade out originates may be due either to a very low spin rotation of the satellite, or to a satellite spin having a period approximately submultiple of the orbital period.

To the purpose of discerning between the two causes, simultaneous observations at several stations should be examined.

In several cases a strong attenuation and a change of modulation pattern occurred simultaneously (see Fig. 4.4 and Table I).

Although the type of transmitted data is not known, it is possible to explain this phenomenon in the following way.

Generally the quantities measured by the satellite, as temperature, particle density, and radiation intensity, vary slowly; therefore the record of the telemetry pulses varies slowly during a passage or varies from one passage to another.

On the contrary, in the case in which the satellite crosses a cloud of greater ionic density or a beam of ionized particles traveling at high speed, a sudden change in the record of telemetry pulses will occur in correspondence with the cross.

Moreover the antennas of satellites could be mismatched because they are inside a zone of high ionic density, and on the other hand a strong attenuation of the signals may happen. Then, the phenomenon which would occur in this case is similar to the observed phenomenon. Due to the position of the satellite at that time, we think that the satellite crossed the upper horn of the inner Van Allen belt.

This phenomenon was observed by other authors also (Liszka, 1961, Kraus, 1960) and could offer a method for localizing the

same belts.

5 - Faraday rotation

Many records have been obtained showing a pure Faraday effect, and a number of them present the so-called 'inversion point'. An example is shown in Fig. 5.1 (upper curve). The records with the inversion point are listed in the seventh column of Table I and have been used for the evaluation of the electron contents in the column between satellite and the ground.

By assuming the horizontal gradient of electron density to be negligible and the high-frequency approximations to be valid, the following equation may be proved

$$\Omega = \frac{K^2}{f^2} H \cos \Theta \sec \chi \int_0^h N(h) dh$$

where Ω is the angle by which the polarization plane rotates due to the Faraday effect, K is a constant, f the frequency, H a mean value of the earth magnetic field, Θ the angle between the earth magnetic field and the ray-path \underline{s} (in the direction from the satellite to receiver), χ the angle between the vertical at the satellite and \underline{s} , h the height of the satellite over the ground, and N the electronic density.

Among these quantities, Ω is the most difficult to determine. However such a difficulty disappears when, during the transit, the satellite passes at a point I where the earth magnetic field is normal to the ray-path \underline{s} (see Fig. 5.2 and 5.3). At this point the rotation angle Ω is obviously smaller than π . A typical record of this kind is shown in Fig. 5.1 (upper curve). Each fade of the amplitude corresponds to Ω varied by π with respect to the preceding fade. Accordingly, at each point of the record Ω is equal to the number of the fades between the considered point and the inversion point I, multiplied by π .

A particular record (Fig. 5.1 lower curve) was obtained on March 1, 1961 at 1747 G.M.T. on the orbit N° 9467. The fading period

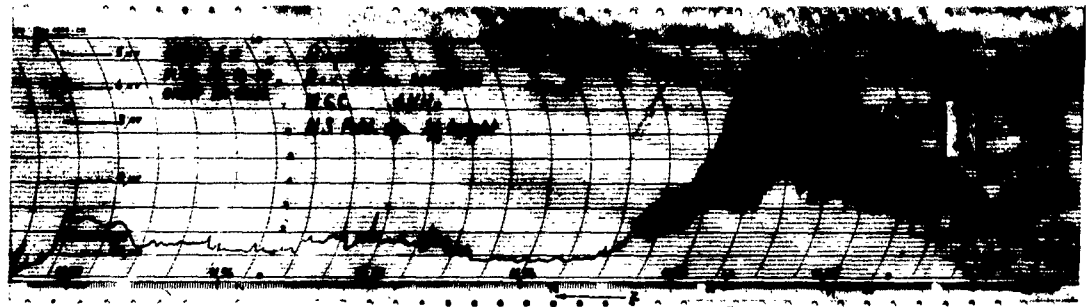


FIG. 5.1

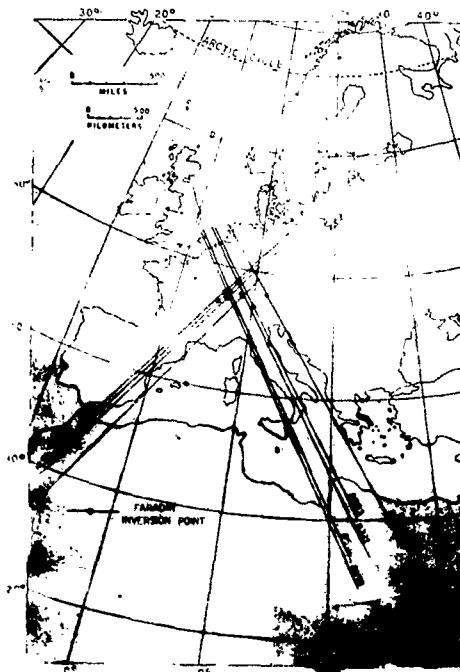
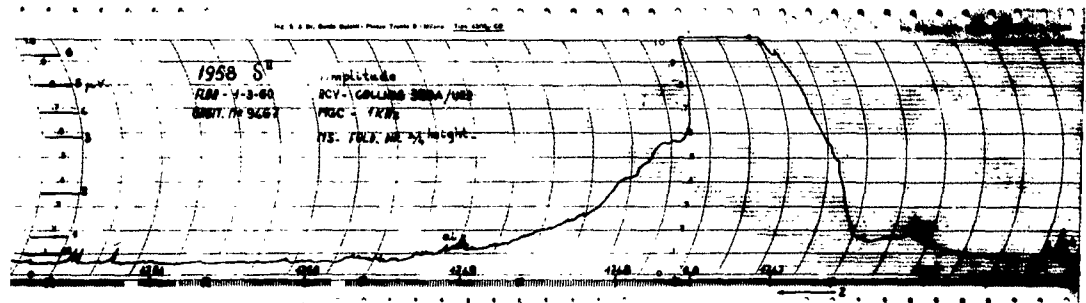


FIG. 5.2

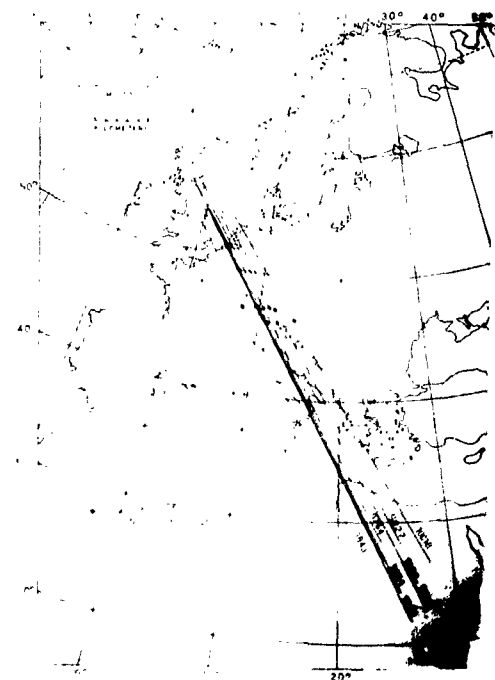


FIG. 5.3

seemed to be very large compared with the reception time, probably due to both a low electron density and small quote.

During the last revolutions of 58 02, several records presented the inversion point. These records allowed the evaluation of the electron contents of the columns. The height of the satellite over the ground varied in the range between 400 and 150 Km.

In order to be close to the conditions in which the straight-propagation path approximation is valid, only records corresponding to small zenith angles have been considered for the evaluation of the electron contents of the columns (Fig. 5.4). The results are shown in the following table.

TABLE II

| REV. | T I M E T.M.C. | | h_s km | $\int_N^S dh \times 10^{16} \text{ m}^{-2}$ N C.A. | S | |
|------|-------------------|------|-------------|---|--------|--------|
| 8321 | 18-12-59 | 1610 | 350 | 10.782 | 11.207 | 11.050 |
| 8502 | 30-12-59 | 1252 | 305 | 9.761 | 11.336 | 12.584 |
| 8532 | 1-1-60 | 1155 | 310 | 4.098 | 12.270 | 7.560 |
| 8623 | 7-1-60 | 1027 | 300 | 5.274 | 13.638 | 14.693 |
| 8699 | 12-1-60 | 0914 | 285 | 7.027 | 9.649 | 10.203 |
| 9843 | 25-3-60 | 1139 | 180 | 1.269 | 1.623 | 2.375 |
| 9954 | 1-4-60 | 0921 | 170 | 0.817 | 0.997 | 0.764 |
| 9970 | 2-4-60 | 0904 | 170 | 1.540 | 1.149 | 1.084 |
| 9986 | 3-4-60 | 0844 | 150 | 0.917 | 0.842 | 0.658 |

In this table, three values of the electron content are given for each revolution. The column C.A, corresponds to the closest approach which occurs at about 44° North latitude. The columns N and S correspond to positions of the satellite (indicated by crosses in Fig. 5.4), which are at North and at South respectively, with respect to the position of closest approach. The corresponding lati-

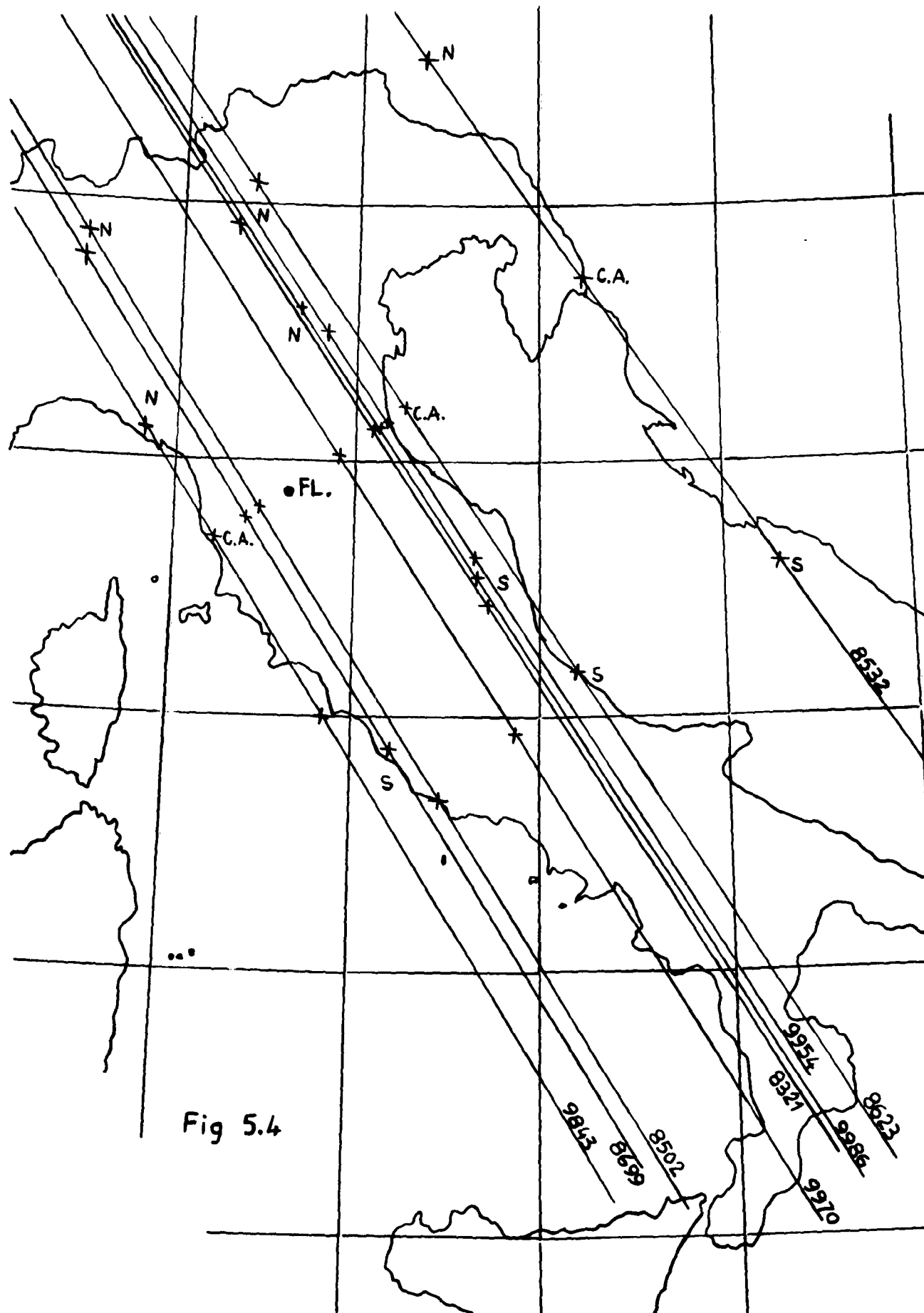


Fig 5.4

tudes are about 46° N and 42° N respectively.

The date, the time of closest approach, and the height of the satellite over the ground are also given.

The appreciable differences existing between the three values corresponding to the same transit indicate changes of ionization with latitude.

6 - Hop Propagation

When the satellite travels at low altitude between 350 and 150 Km, a typical phenomenon occurs due to the hop propagation (Fig. 6.1). Many records present a typical pattern (Fig. 6.2) where bursts of signal can be noted before and after the closest approach.

In addition, in this case the Doppler curve is sometimes affected by a strong phase jump (see Fig. 6.3).

In order to prove that this phenomenon is due to the hop propagation, the skip distance has been evaluated by using the ionosonde data. Fig. 6.4 shows the results. In this figure the sub-satellite track is drawn for a number of orbits and the position of the satellite at the time at which the burst occurs is marked. Further, portions of circles are drawn having radii equal to the evaluated skip distances (and centered at Florence).

It appears that such circles cross the orbits in the zones corresponding to the observed bursts. However, a discrepancy may be noted with regard to the north observations. This is most likely due to the fact that, in evaluating the skip distances, ionospheric data measured at more southern latitudes of the reflection points are used.

The records of the type shown in Fig. 6.2 present two other phenomena, and namely:

- 1) a double burst on each side of the closest approach position,
- 2) a periodic fade at the rise of the two bursts preceding the closest approach and at the decay of the two bursts following the closest approach.

The double bursts are due to the ordinary and extraordinary rays.

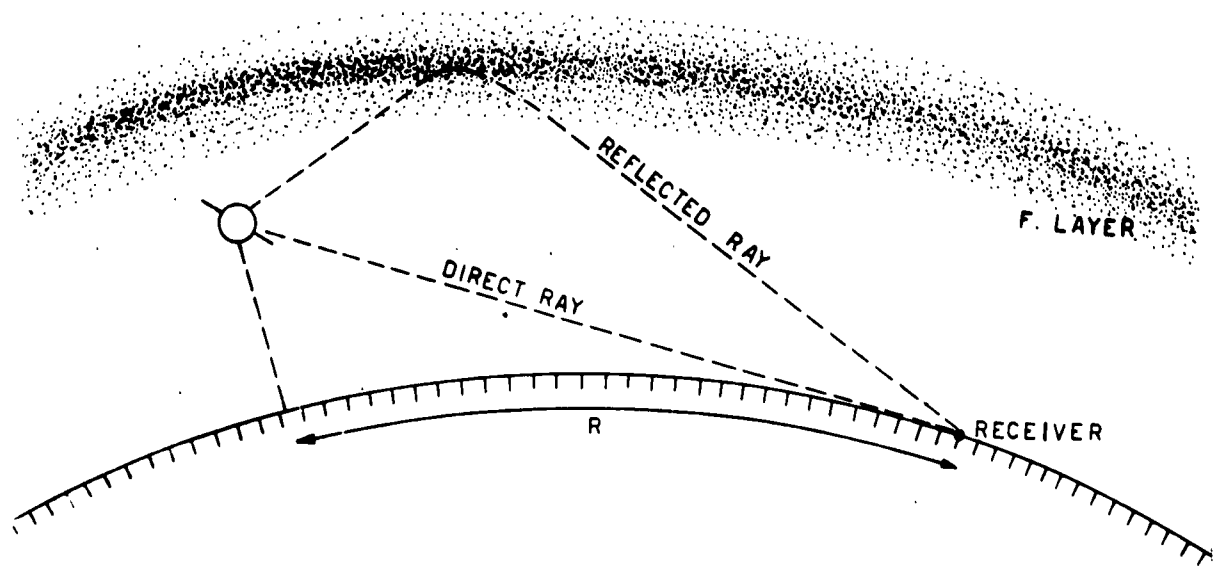


Fig 6.1

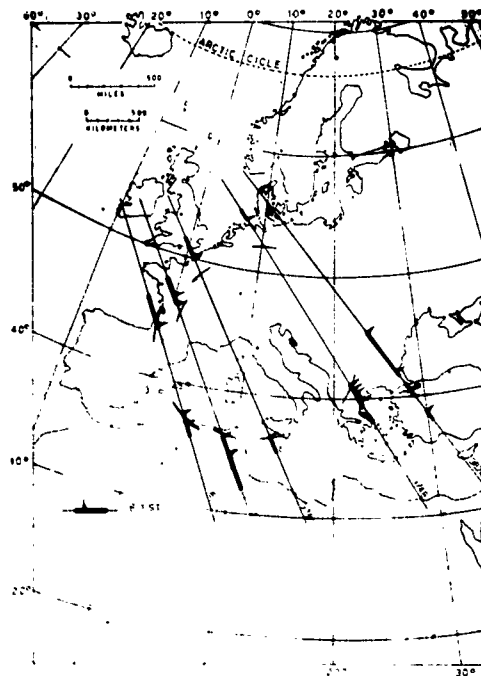


FIG 6.4

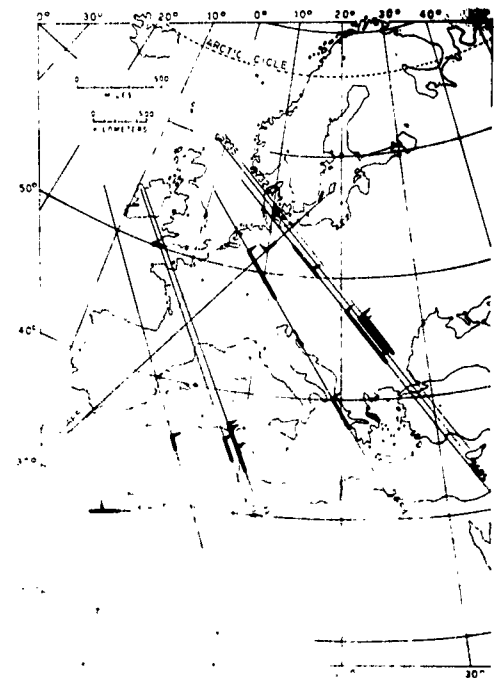


FIG 6.5

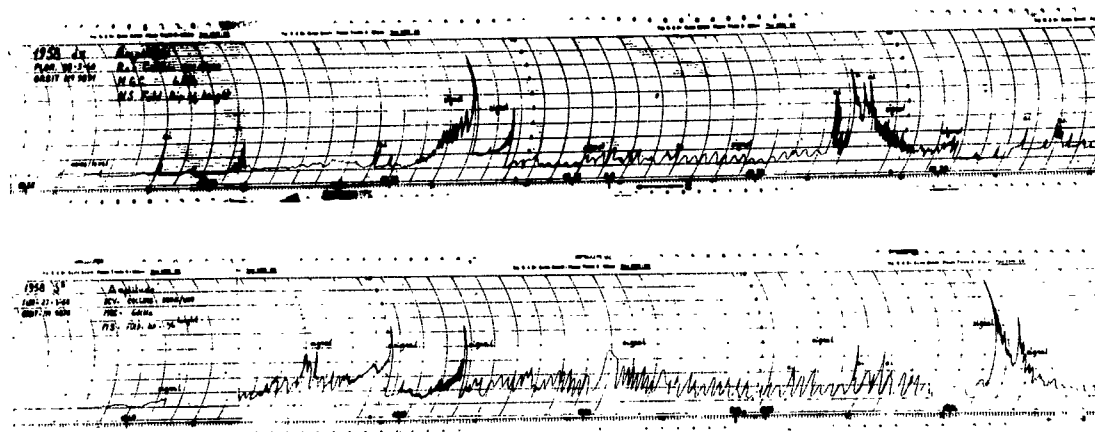


Fig.62

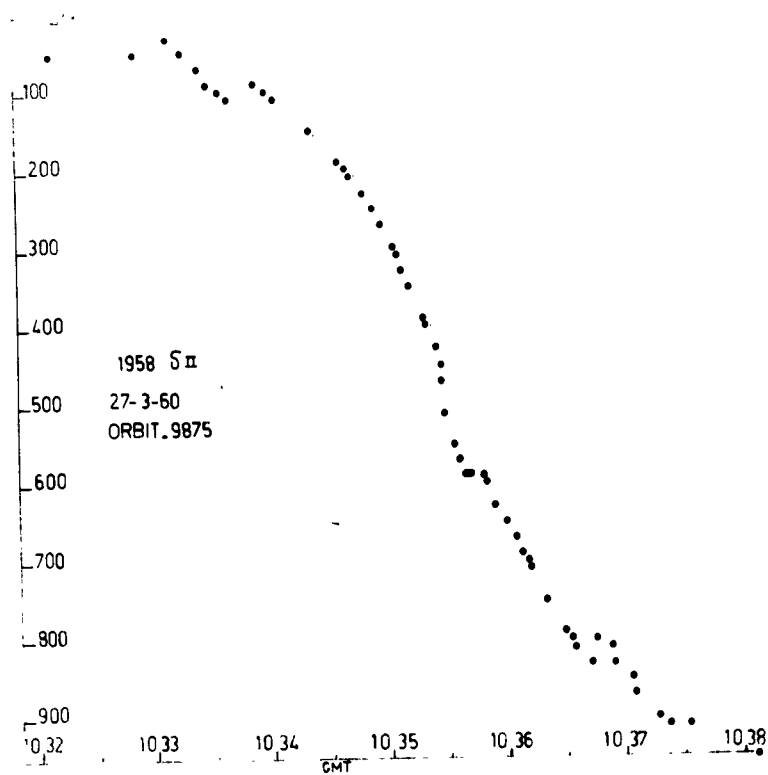


Fig 53

The periodic fade is due to the interference of the direct wave and the wave reflected by the sky (Fig. 6.1).

The Fig. 6.5 indicates the subsatellite track for other revolutions on which we recorded the 'bursts'.

The severe mismatch imposed to the satellite antenna by the ionization around the satellite may be the cause of the low level signal in the nearness of the closest approach.

We point out that low altitude beacon satellites, obviously of short life, orbiting below the maximum of F region may constitute a powerful means of investigating the long-distance hop-propagation phenomena since they allow the sounding of a continuous varying propagation path around the earth.

7 - Conclusion

In the preceding sections we have described the methods employed at Centro Microonde for studying the ionosphere by means of artificial satellites signals and the work developed in this field.

In the period we examined the signals suitable for this work, those emitted by 1958 0II. As above noted it was very difficult to measure the frequency shift with great accuracy because of the pulse modulation of the signals of this satellite.

By means of Faraday rotations we performed some determinations of the integral electron content in the column between the satellite and the ground.

It was also possible to explain the hop-propagation phenomenon in agreement with the computed values.

We did not make deductions from phase and amplitude scintillation records or from fade out records, but we think that it may be useful to list here the periods during which these phenomena occurred, and also to represent the corresponding positions of the satellite.

These data could be utilized by comparing them with the observations made by other stations with the purpose of localizing the zone of ionospheric irregularities which caused scintillation.

In the future we plan to utilize the signals emitted by beacon ionospheric satellites S-45, which will be soon launched, for continuing these observations.

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